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STUDY OF M831A1 OBTURATOR BAND ASSEMBLY, PROBLEMS, AND SOLUTIONS

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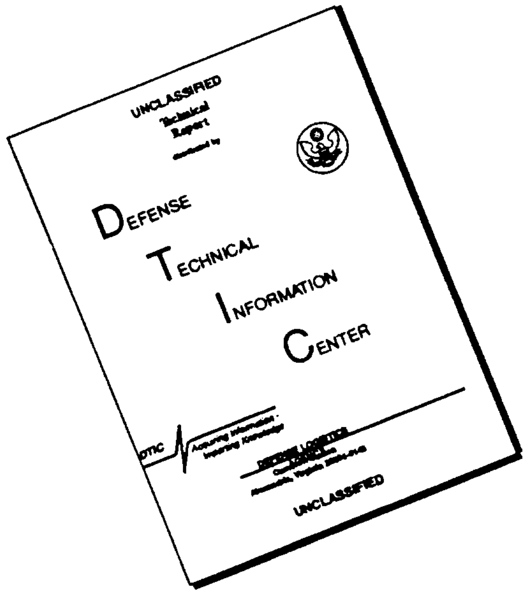

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This report details the testing that was done to evaluate various methods to assemble obturators onto the M831A1. The obturators were assembled to the M831A1 using four different methods and subjected to various temperature/humidity conditions. The swelling of the obturator was measured and recorded for comparison. In addition, pass/fail was recorded for a ring gage test.

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INTRODUCTION

The M831A1 Target Practice-Tracer (TP-T) is a 120-mm tank cartridge used as a trainer for the 120-mm M830 High Explosive Antitank (HEAT) round. The M831A1 (fig. 1) replaces the M831 (fig. 2). The M831A1 was a cost savings program which the U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ estimated saved $200* per round as compared to the cost of the M831.

The M831A1 cartridge has the exact outside appearance as the M831 except for the obturator band, which is made of copper on the M831 and 6/6 nylon on the M831A1. There are other differences between the M831A1 and M831, however, they are all on the interior of the cartridge. The M831A1 is a ballistic match to the M831.

The in-flight projectile (fig. 3) consists of a spike, body (the spike and body together are called the projectile head), seal, ring, and stabilizer. The obturator is located on the body and is assembled in a groove, which is machined on the aft of the body.

The M831A1 cartridge was developed from 1989 to 1992 and Type Classified (TC) in April 1993. The M831A1 cartridge was materiel released (MR) in September 1994 and fielded for soldier training in 1995. The operational temperature range requirements of the M830 and M831A1 are from -25° to 125°F. The safety and storage temperature requirements are from -50° to 145°F.

BACKGROUND

The purpose of the M831A1 obturator is to prevent propellant gases from getting past the projectile upon ignition of the cartridge in the tank gun. This allows the projectile to get the most velocity from the expanding propellant gases. In addition, if propellant gases get past the obturator (called gas wash), the velocity that the projectile attains upon leaving the gun (muzzle velocity) would vary greatly. In order to get good repeatable target impact dispersion (TID) at 2,000 m (the user requirement) on the target, the muzzle velocity must be repeatable, therefore, gas wash is unacceptable. As the in-flight projectile leaves the gun, the obturator band may either stay on or come off. If the band comes off, it must come off cleanly without getting hung up on any part of the projectile. If the band hangs up, it will affect the flight of the projectile causing poor TID and possibly a safety hazard if it causes the projectile to go outside its intended flight path.

*FY96 money.

Several thousand M831A1 cartridges were fired during development, TC, and MR testing. Data on obturator performance for each of these tests were gathered and analyzed. In-flight obturator performance is shown for each round by either smear or hadland photos (fig. 3). These photos are stop action photos taken several feet from the gun muzzle which clearly show the obturator. The obturators are either still on the projectile or separating from the projectile as the projectile leaves the gun, as witnessed by the photos. It was determined that about half the time the obturators stay on the projectile during flight and half the time the obturators come off. When the obturator came off, it either broke into several pieces or broke in one place and came off as a ribbon. It was also shown that once the obturator came out of the obturator seat, it broke and did not hang up on the projectile.

In order to ensure that the nylon obturator would perform equally well in production, several records were established during the development and testing of the M831A1. These included documenting the physical properties of the obturator and the process used to put the obturator onto the body. This knowledge was shared with the system contractors that would eventually build the M831A1 in production.

The process of putting the obturator on the M831A1 body was developed at the ARDEC machine shop. Past experience was used, since other tank cartridges use nylon obturators. Once the process was optimized, it was used to put obturators onto M831A1 metal parts used during the M831A1 development phase testing. All metal parts for these obturators were made at ARDEC. The obturators were either machined from nylon rod at ARDEC or purchased from a contractor.

Several hundred M831A1 obturator bands were successfully placed onto M831A1 bodies using the same optimized procedure. In order to check the validity of the M831A1 design and technical data package (TDP), 250 M831A1 projectile heads (including obturators onto bodies) and stabilizers were manufactured by a contractor that made 105-mm tank cartridge metal parts. The procedure and technology to place the obturators onto the bodies was transitioned from ARDEC to the contractor in order to validate its usefulness. Once these 250 metal parts were successfully manufactured and ballistically tested, it was time to manufacture the M831A1 cartridges for TC testing.

The requirement is that the TC cartridges be manufactured in the same production environment that will be used to manufacture cartridges for the user. There are only two system contractors for the 120-mm tank cartridge production. A competitive solicitation to manufacture 1,200 M831A1 cartridges for technical test/user test (TT/UT) was provided to both of these contractors. Technical test/user test is the test needed for TC. Once a system contractor was chosen, the technology and TDP to manufacture the M831A1 was turned over to this contractor. Using the TDP and making visits to

ARDEC to see how obturators were put onto the M831A1 bodies, the system contractor manufactured 1,200 M831A1 cartridges meeting all requirements including obturator band requirements (figs. 4 and 5). These requirements were determined using all the data from the testing to date. Physical characteristics of the obturator bands that had been used to date were determined at -32°, 21°, and 52°C and included as requirements in the TDP.

All cartridges and obturators tested in TT/UT performed well. The remaining cartridges were used as controls during MR testing and also performed well.

Following TC and MR, the final TDP was turned over to both system contractors for production. The system contractor that had produced the TT/UT M831A1 cartridges had problems putting on the obturators for the first production lot. After consultation with ARDEC, the contractor reported that the problem was resolved. It appeared that discolored obturators (brown verses the usual white) had created the problem. ARDEC tested obturators from this contractor and found that they did not meet the physical properties of the TDP. A letter was sent to the system contractor to identify this shortcoming but was not resolved.

Several lots of M831A1 production from both system contractors were completed and shipped to the user. The system contractor that had the problem before putting on the obturators, notified ARDEC that it was again having problems. It was determined that the contractor was experiencing over 50% failure of the obturators passing the ring gage test after putting on the obturator. This was up from about 10% failure from the other lots that had been produced. In addition, the contractor was using a ring clamp method to rework the obturators so that they could pass the ring gage. This procedure was not approved by ARDEC.

The contractor asked ARDEC to evaluate and possibly approve the ring clamp procedure in order to bring the obturators into conformance. In addition, another procedure called a boiling procedure (in reality a hot water treatment) was submitted for approval. They also asked ARDEC for help in solving the problem of putting on obturators without failure by helping optimize their existing process.

Further investigation showed that both system contractors were getting their bands from the same company. The other contractor, not experiencing problems, was following ARDEC's recommended procedures and was having close to zero rejects.

ARDEC worked with the contractor having the obturator problems, to recommend improvements to their process. Advice was given on the areas to review that affected obturator assembly. In addition, temperature and humidity and physical property tests were run on the obturators at ARDEC to evaluate the proposed clamping and boiling procedures. Temperature/humidity tests were run on the obturators/bodies [obturators on bodies were supplied by the contractor and had been subjected to each procedure (i.e., clamped, not clamped, and hot water)]. Physical properties were done on the production obturators in accordance to specification, in order to verify that they meet the specification.

Following advice from ARDEC and experimentation, the contractor was able to reduce the obturator ring gage failures to almost 0%. Several lots were produced since improvements were made to the process with continued 0% failure. The testing at ARDEC for the clamp and hot water method and the physical properties of the obturator were completed. Results are contained in this report as well as a discussion on the key areas to concentrate on when putting the 6/6 nylon obturator onto the M831A1.

DESCRIPTION OF ARDEC M831A1 OBTURATOR ASSEMBLY

General Description

The M831A1 obturators are supplied by the manufacturer in sealed plastic bags. The obturators are removed from the bags as needed and temperature conditioned in an oven before installation onto the body. The bands are temperature conditioned in the oven at 116° ± 5.5°C for 30 to 120 min. The M831A1 body and obturator band seat is cleaned prior to assembly of the obturator onto the body.

Figure 6 shows the setup for the installation of the obturator onto the body. The body is placed onto the press, aft end up, and is held in place by a nest. An aluminum ramp with a nylon insert (fig. 7) is placed on the body. The nylon insert goes into the M831A1 body thread area and centers the ramp. The ramp is always placed on the side of the M831A1 body closest to the obturator band seat. The obturator is removed from the oven (fig. 8) after conditioning and immediately put on the ramp. A nylon two piece pusher is placed onto the press (fig. 9). This pusher has a spring on the exterior that allows it to expand as it rides over the ramp pushing the obturator onto the body and into the obturator band seat. This pusher is used over and over again. It also protects the obturator from the press.

The press is turned on and pushes the obturator into place within a few seconds. The body is then removed from the nest and placed on a table, allowing the obturator to cool.

This procedure is repeated until the obturators in the oven have all been used. Care must be taken while the obturator is being pushed on to wear safety glasses, since occasionally an obturator may break off and fly into the air. No more obturators are put into the oven than can be put on within the time constraints of the heating requirement.

When the hot obturator is first put onto the body, it is stretched and therefore loose in the obturator band seat. Within several minutes, however, properly put on obturators will cool and shrink to become tight around the obturator band seat. This is an indication that the machine and method used to put on the obturator are working correctly. Not all obturators become tight when placed onto the body. It is recommended that the method used be refined until a maximum amount of tight obturators can be achieved.

A go and no go ring gage is used to determine that the obturator outer diameter is acceptable. If the obturator does not pass through the go ring gage, then there is a possibility that it will not have enough clearance to chamber in the gun. If it passes through the no go gage, then there is a possibility that it will not obturate properly inside the gun and allow propellant gases to pass by the obturator.

Important Key Process Areas for Proper Installation

The method given for installation of the obturator is a general one. What is important is that the process must be adjusted and refined to focus in on the key areas of obturator installation. Through experimentation, the process may be adjusted to optimize the machinery and methods used to get optimized installation of the obturator.

The key areas that may be adjusted are as follows:

1. Obturator band seat diameter on body.

2. Oven: Temperature, circulated even heat flow in the oven, ensure heat is distributed evenly throughout the oven, and shelves do not block heat flow, use a door that is easily opened and closed and will minimize heat loss whenever opened.

3. Ramp: Use a ramp that has the most gradual increase in angle. Sometimes a longer ramp is preferred to achieve this. The diameter at the top of the ramp should center a heated obturator to minimize twisting of the obturator as it is pushed on.

4. Machine or Press: The rate the machine can push on the obturator is important. It appears that quicker may be better. The length of travel the press can go may limit the size ramp used. Hydraulic verses pneumatic. Hydraulic is less forgiving since liquids do not compress. Pneumatic has more give and may shock the obturator less since air has some compressibility.

5. Inner and outer diameter of obturator.

6. Thickness of obturator band and grooves.

7. Physical properties of obturator band: Load to break, extension at break, moisture content, specific gravity, physical appearance, and color (variations in obturator color may indicate that manufacturing process changes may have occurred that may effect physical properties).

8. Insure obturator is 6/6 nylon and not 6/12 nylon as per ASTM D4066.

9. Cracks and bubbles will weaken band and may cause band to break when being put onto body.

10. Humidity/temperature of building: Excess humidity or temperatures should be avoided. To date, however, bands have been installed successfully in buildings that are not temperature controlled.

Past ARDEC Obturator Work

In addition to work on optimization of the hot oven method to put on obturators, ARDEC also looked at other methods and materials.

Work was done at ARDEC to study the effects of heating the obturator in water instead of the oven and then placing the obturator on the body. It was felt that the water treatment would saturate the 6/6 nylon, which is slightly hygroscopic. After being put onto the body, it would be less likely to swell when stored long term and possibly subjected to moist conditions. The obturator swells when subjected to hot/humid conditions, especially if it had low moisture content before exposure. As the obturator swells it may prevent chambering in the gun.

The water method was very successful and many water temperatures near the boiling point of water were tried. All worked equally well. The drawback was that this was viewed as a less production doable option and therefore was not chosen as an option for the TDP. Obturators which were put on using water as the heat source were never ballistically tested. If this method was ever used, it would have to be ballistically tested to ensure the water method did not change the properties of the obturator band. Of specific concern would be that the water may make the obturator band tougher and/or more elastic. If so, it may not break when the obturator comes out of the obturator seat on the body when ballistically fired. If this happened, the obturator would hang onto the projectile and alter its flight.

Since 6/6 nylon is slightly hygroscopic and tends to swell when stored for long periods of time, ARDEC pursued assembly of 6/12 nylon bands onto the M831A1. The 6/12 nylon is more expensive, but is less hygroscopic than 6/6. Many different methods such as the oven, hot water, etc. were tried. ARDEC was unable to get the 6/12 nylon to return to shape after being pushed onto the body. There were other options still available to try; however, limited funding prevented further research in this area.

DESCRIPTION OF TEMPERATURE/HUMIDITY TESTS

The systems contractor that was unable to pass the ring gage requirement after assembly of the obturator onto the M831A1 body, submitted two separate procedures to ARDEC for consideration into the TDP. It was hoped that these procedures would allow the contractor to pass the ring gage requirement after the obturator is put onto the body. The first procedure was a rework procedure where a clamp would be used to bring the out-of-round obturators (too big to pass through the ring gage) into round immediately after being pushed onto the body. This procedure was to be done when the obturators returned to ambient temperature. It was shown that once the clamp was applied and the assembly reheated, the obturators would be tight against the body and brought into round, therefore, easily passing the go ring gage. The second procedure was a treatment in hot water for the obturators, instead of the oven. It was hoped that either of these methods would be a fall back if the current method of putting on the obturators could not be improved to a near 100% pass of the ring gage requirement. These methods are two separate methods and were to be considered separately. The hot water treatment method worked well as did the clamp method and both appeared to give 100% passage of the ring gage tests.

The problem with the two methods submitted was that ARDEC felt that the contractor had not optimized the current method being used to put on the obturators. Therefore, undue stress was being put on the obturator forcing an out-of-round condition. The clamp only forced the obturator back to round, but may still have internal stresses that will cause the obturator to go out of round when stored in a hot/humid environment. The hot water method was also questionable since it would require expensive ballistic tests to ensure that the properties of the obturator were not changed. The long term storage characteristics were not known. Consequently, there was concern that the obturator may get hung up on the projectile during flight if it did not break when it came out of the obturator band seat on the body. The water treatment method was not as production usable (time and cost) as the existing dry oven method.

In order to study the validity of the submitted methods and determine their long term storage in hot/humid conditions, tests were conducted. Criteria considered includes the long term storage expectations of a training round and the worst case temperature/humidity environment it would be exposed to. It was decided to test the extreme storage condition of 145°F/95% RH for approximately 1 mo. Testing showed this to be too extreme, since all obturators swelled to an oversize condition. Review of the test procedure concluded it was an overtest since the average training round sees less than 6 mos storage and usually a maximum storage life of less than 2 yrs. The U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland performs high humidity storage tests at approximately 95°F for less than 2 wks to predict safe storage and performance of 20 yrs. The test was repeated with a new batch of obturator/bodies subject to 95°F/95% RH for approximately 2 wks.

The appendix shows the actual test plans (test plans 1 and 2) as submitted to ARDEC's Armament Engineering Directorate (AED) PLASTICS, where the testing would be done. Some slight deviations to the plan were performed because of a shortage of materials and a malfunction in the temperature/humidity cabinet (fig. 8).

The following paragraphs provide a summary of the temperature/humidity tests that were performed. All bodies with obturators in place were assembled at the contractors facility using the method specified (clamped, boiled, etc). These parts were supplied to ARDEC. The obturators were measured and ring gaged before being put into the cabinet (fig. 10) and every time they were removed and examined. All obturators passed the ring gage before they were subject to temperature/humidity tests.

Test 1: Five obturator/bodies--regular method (marked NC for not clamped), 10 obturator/bodies--clamped method (marked C for clamped), and five obturator/bodies--hot water method (marked W for hot water) were subjected to 24 hrs in the cabinet set at 145°F/95% RH, removed and examined. Placed back into the cabinet for 13 days, removed and examined.

Test 2: Ten obturator/bodies--regular method (marked R for regular), 10 obturator/bodies--hot water method (marked W for water), and 10 obturator/bodies--clamped method (marked B for bands) were subjected to 3 days at 70°F/unknown RH (cabinet RH was broken and then repaired), removed and examined. Placed back in the cabinet for 12 days at 95°F/95% RH. The markings for these two tests are confusing because the contractor used different symbols for the same procedure. It was later discovered that a different person had prepared the samples.

Test 3: Three obturator/bodies--regular method, three obturator bodies--clamped method, and three obturator bodies--hot water method were subject to a regular oven for 3 days at 115°F/low humidity, removed and examined and then 1 wk at 145°F/low humidity.

Test 4: ARDEC had worked with the contractor to improve their regular method. This effort followed the "key process areas" aforementioned in this report. After optimization of their obturator assembly, a 100% passage of the ring gage was achieved. It was, therefore, decided to test the improved method obturator/bodies in the temperature/humidity chamber. Nine of these obturator/bodies were put into the chamber for 7 days at 95°F/95% RH and then examined. They were put back into the chamber for another 7 days at 145°F/95% RH.

DESCRIPTION OF PHYSICAL PROPERTY TESTS

Thirty-two obturator bands were supplied from the contractor to ARDEC to test for conformance to the physical property requirements of the Band, Obturator drawing 12944389 (fig. 5). The bands were taken from regular production. Measurements were taken of the inside and outside diameter, thickness, and height of each obturator. A vernier caliper was used to measure the obturators. The following physical properties were determined:

Load to break at -35°, 73°, and 140°F
Extension at break at -35°, 73°, and 140°F
Moisture content
Specific gravity

Load to break and extension at break: An Instron Tensile Tester, Model TTD (fig. 11) was used to perform the tensile and elongation tests. The crosshead speed for this test was 0.5 in./min.

Moisture content: Obturators were weighed on an analytical balance. This was recorded as the initial weight. The obturators were placed in an oven at 160°F for 24 hrs. They were cooled in a desiccator and reweighed. They were reheated and reweighed until a constant weight was obtained. This is the conditioned weight. The moisture content is obtained by the following equation:

$$\text{moisture} = \frac{\text{initial weight - conditioned weight x 100}}{\text{initial weight}}$$

Specific gravity: The specific gravity of the obturators was determined in accordance with method ASTM - D792.

TEST RESULTS

1. Corrective methods were used by the system contractor and the process of putting on the obturator was optimized. As a result, after putting on thousands of obturators since the improvement, almost 0% rejects of the ring gage test were experienced. This compares to the 10% to 50% reject rate that was experienced before optimization.

2. Results for the temperature/humidity tests for the obturator/bodies are shown in tables 1 through 4. These tables show details of the measured values of the obturator at the various stages of the test, as well as whether it passed the ring gage (GO). A summary of the ring gage (GO ring gage) results are as follows (all test items ring gaged before being subjected to any test):

Test 1 (Temperature/humidity cabinet):

Item start of test (all passed at test start)	24 hrs 145°F/95% RH passed	Additional 13 days 145°F/95% RH passed
5 not clamped (NC)	0	0
10 clamped (C)	9	0
5 hot water (W)	5	0

Test 2 (Temperature/humidity cabinet):

Item start of test (all passed at test start)	3 days 70°F/RH unknown passed	12 days 95°F/95% RH passed
10 not clamped (NC)	7	0
10 clamped (C)	7	1
10 hot water (W)	7	4

Test 3 (Low humidity oven):

Three from each of the not clamped, clamped, and hot water for a total of nine were put into an oven with low humidity. They were subjected to 95°F/95% RH for 3 days and then 145°F/95% RH for 7 days. All test items passed the ring gage (GO) for all phases of this test.

Test 4 (Temperature/humidity cabinet):

Using the improved procedure to put on the obturator, nine of these obturator/bodies were placed into the temperature/humidity cabinet so that a comparison to the other methods (NC, C, and W) could be made. The following is the results for the ring gage (GO) test:

Item start of test all passed at test start	7 days 95°F/95% RH passed	7 days 145°f/95% RH passed
9 new procedure (NP)	9	2

3. Physical property test results are shown in table 5. The following test items did not pass the specification requirements, all other items shown on table 5 passed the requirements:

   - One of the five obturators tested for load to break, conditioned to room temperature, did not pass the requirement of minimum 3,410 lb force. Its value was 500 lb.

   - One of the five bands tested for load to break, conditioned to 140°F, did not pass the requirement of minimum 2,838 lb force. Its value was 420 lb. Two of the five bands did not pass the extension to break, conditioned to 140°F, requirement of 1.5 to 6 in. Their values both exceeded 6 in.

   - Three of the five bands tested for load to break, conditioned to -35°F, did not pass the requirement of minimum 4,884 lb force. Their values were 200, 700, and 690 lb.

   - Two of the two obturators tested for moisture content failed the requirement of 0.2 % maximum. Their value were 0.26% and 0.29%.

DISCUSSION OF RESULTS

The assembly of the obturator onto the M831A1 was outlined by the ARDEC procedure. The TDP reflects the basic variables that need to be controlled, such as temperature, time of exposure to temperature, obturator diameter and thickness, and physical properties of the obturators. These controls only provide the minimum control that is needed to properly assemble the obturator onto the M831A1 body. In order to optimize the assembly process, trial and error adjustments are required. A goal of optimization is to achieve almost 100% passage of the ring gage test. Properly installed obturators should be able to ring gage within a few minutes of installation.

The temperature/humidity tests were done on obturators installed on bodies using several methods which include: the improved optimized method, previous regular method, clamped method, and hot water method. The clamped and hot water methods used the regular method to put on the obturator, and therefore were additions to the regular method. The optimized method was similar to the regular method; however, improvements in the machine, ramp, and oven conditioning changed the ring gage failures from almost 50% to near 0%. The optimized method was not a cost increase as compared to the regular method.

Reviewing the results from high temperature/humidity tests 1, 2, and 4, and high temperature/humidity tests, it can be observed that there may be internal stresses on the obturator when improperly installed. These stresses may be relieved when the obturator is exposed to high humidity and goes out of round, creating a ring gage failure. The optimized method may have less internal stresses and can better survive high humidity. Test 3 shows that high heat alone (up to 145°F) does not affect the obturator and passage of the ring age.

The results for test 1 show that the regular, clamped, and hot water methods after 14 days exposure to 145°F/95% RH had 0% passage of the ring gage. A ring gage test prelook at 2 days conditioning also had 0% passage; the test was continued, however, so that measurements with the caliper could be taken following completion of the test. Test 2 for the regular, clamped, and hot water methods after 12 days exposure to 95°F/95% RH had 0/7, 1/7, and 4/7 passage of the ring gage test, respectively. The optimized method, without the additions of clamping or hot water preheat, had 9/9 passage of the ring gage following exposure for 7 days at 95°F/95% RH and then 2/9 passage of the ring gage after an additional conditioning of 7 days at 145°F/95% RH. In addition, the obturator bands were still tight around the body for all the optimized method test samples conditioned for 7 days at 95°F/95% RH and 7 days at 145°F/ 95% RH. The majority of the samples for the regular, clamped, and hot water methods were loose after 2 days when exposed to 145°F/95% RH.

The temperature humidity data indicates that the optimized obturator assembly method will provide an M831A1 projectile with an obturator that will survive storage in wet locations better than the previous regular method. The clamped and hot water methods show improvement over the previous regular method, but are not as preferred as the optimized method for several reasons. These methods appear not to provide the same wet location storage survivability, are more expensive to use in production, and require more time per obturator to complete installation.

The testing of the obturator for physical properties is needed to assure that the obturator will perform as expected. The obturator must smear back and provide a gas seal as the projectile proceeds up the gun barrel. The obturator must break and not get hung up on the in-flight projectile if it comes out of the obturator seat. The obturator must also be able to remain in shape on the M831A1 for a minimum of 2 yrs storage with as little swelling as possible so that it will not prevent chambering of the cartridge in the gun. The physical property tests provide the information needed to assure that the obturator will function properly and achieve its intended purpose. The physical property test results show that the production obturators do not meet all the TDP requirements. Certification from the supplier of the obturator bands show that the bands do meet all the requirements. Therefore, a round robin test has been proposed.

This will determine if the obturators are truly out of spec or if there is a difference in the testing methods or machinery between ARDEC and the obturator supplier that is causing the discrepancy. Since the obturators have all been performing well in ballistic testing to date, there is a possibility that if the ARDEC results are correct, it may be necessary to examine if a change in requirements is needed. If the ARDEC equipment or the methods are the problem, then this needs to be addressed and fixed. This may also be true for the obturator manufacturer.

CONCLUSIONS

1. The obturators using the three procedures [regular (not clamped), clamped, and hot water methods] swelled when exposed to elevated temperatures and high humidity of 95°F/95% RH and 145°F/95% RH. This swelling caused the obturators to go out of round and fail the ring gage.

2. Optimization of the regular method (optimized method) provided an obturator/body assembly that swelled less than the other methods tested.

3. The optimized method had minimal swelling at 95°F/95% RH. Swelling with this method was seen at 145°F/95% RH; however, it was substantially less than that observed with the other methods. This was the only method that had some of the test items pass the ring gage at 145°F/95% RH (two of the nine obturators).

4. Elevated temperature (dry heat up to 145°F) alone will not cause the obturators to go out of round.

5. The obturators did not meet the physical property requirements on drawing 12844389.

6. The optimized method is a better assembly method than any of the other methods considered. It will provide the following benefits:

    - Less swelling and out of round when exposed to high temperature and humidity

    - Lowest cost due to near 100% passage of ring gage

    - Production doable without any rework procedures or added procedures

RECOMMENDATION

The recommendation from the U.S. Army Armament Research, Development and Engineering Center (ARDEC) is that optimization of the assembly method to put the obturator on the M831A1 body should always be done. This should be done when starting up new production or when approximately 100% of passage of the ring gage is not being achieved. The additional methods of clamping and hot water conditioning are not preferred and will add cost to the assembly. Also, by forcing the obturator into shape with a clamp, internal stresses may be induced in the obturator which may cause the obturator to return to out-of-round condition during storage. The hot water method is not tested ballistically and will not add any more benefit than putting it on with an optimized method. Therefore, the clamp method and hot water method are not recommended.

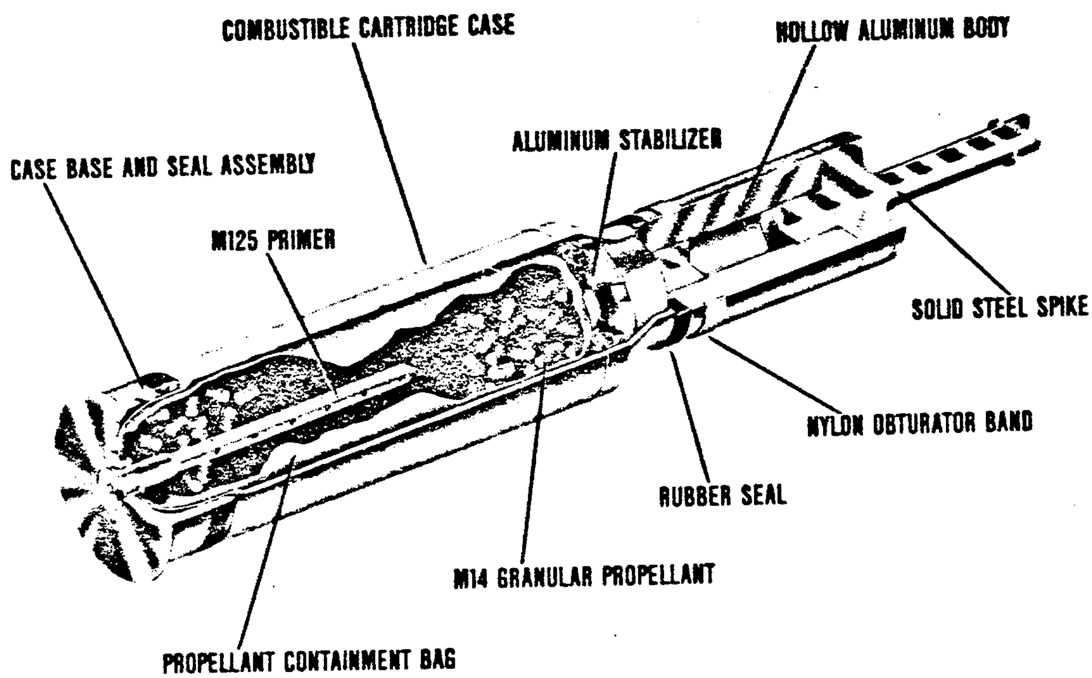
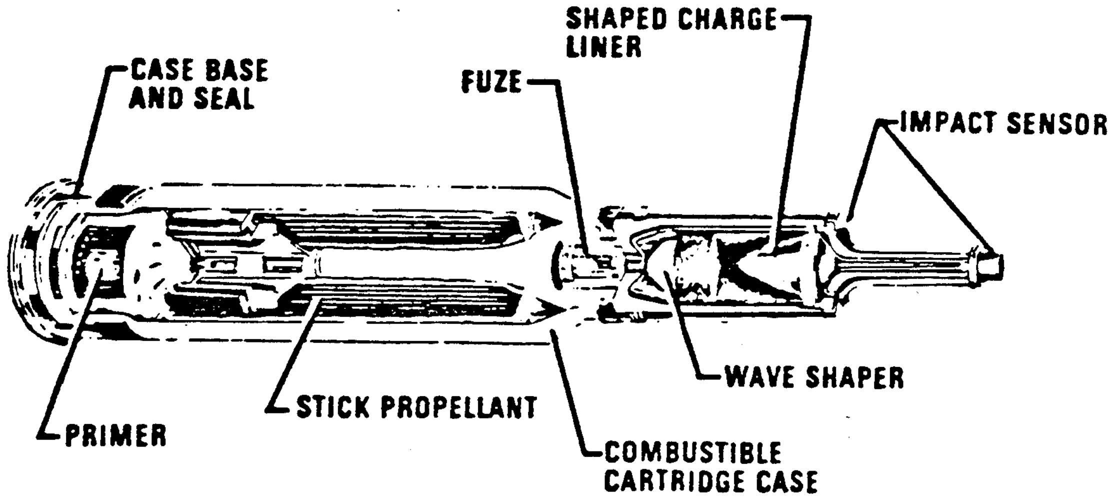
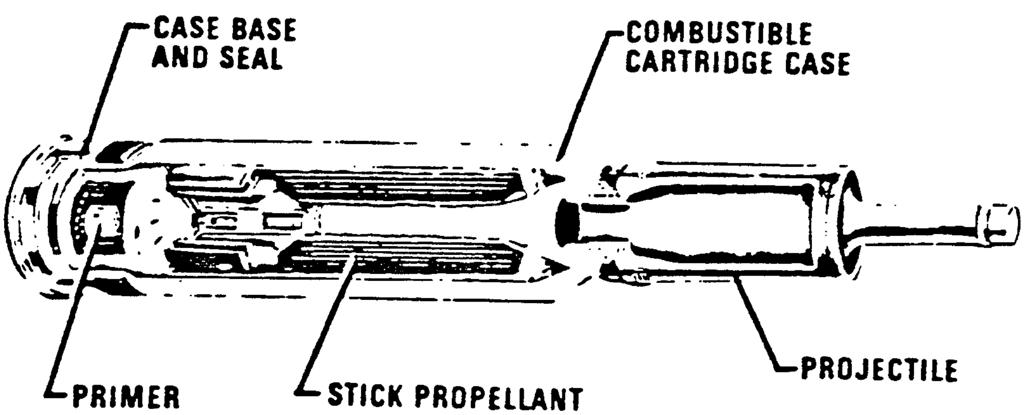


Figure 1
Cartridge, 120-mm, TP-T, M831A1

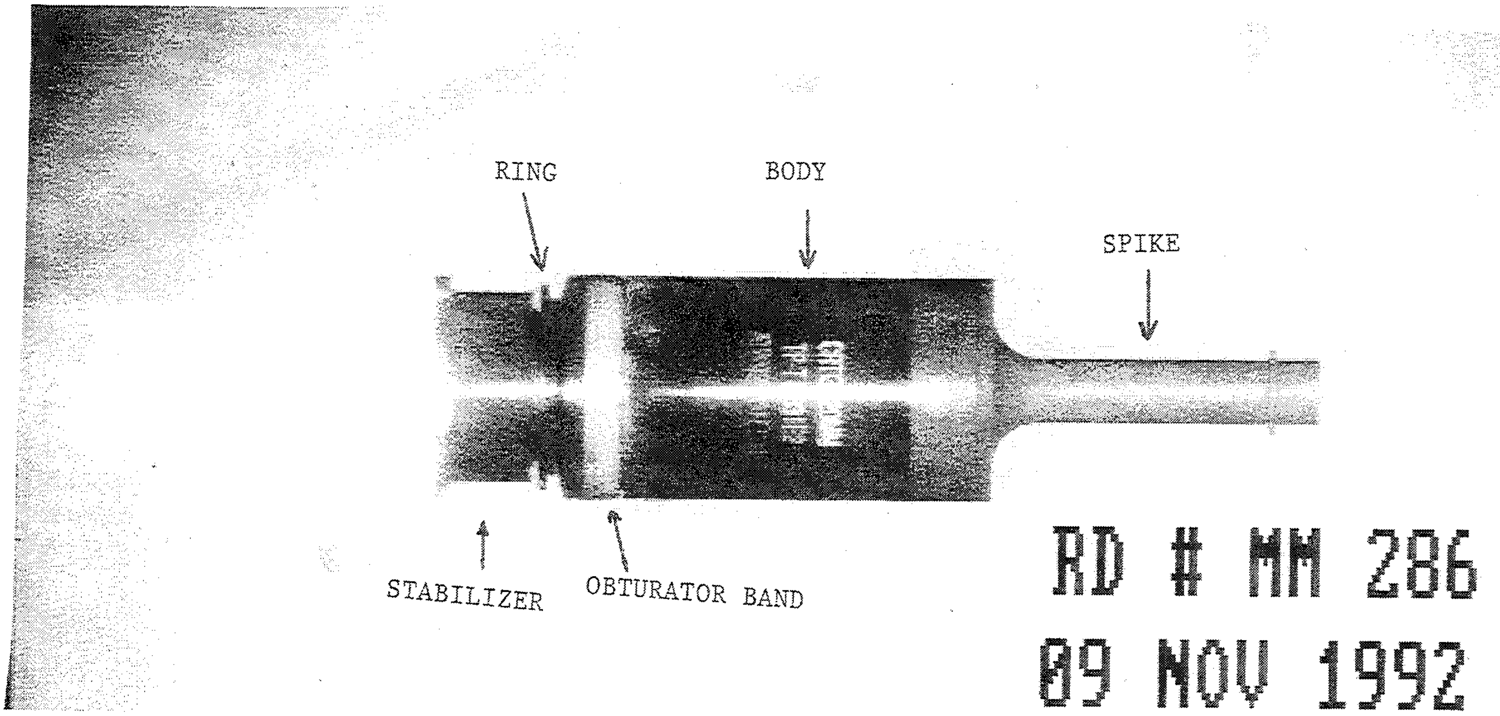


Cartridge, 120-mm HEAT-MP-T, M830

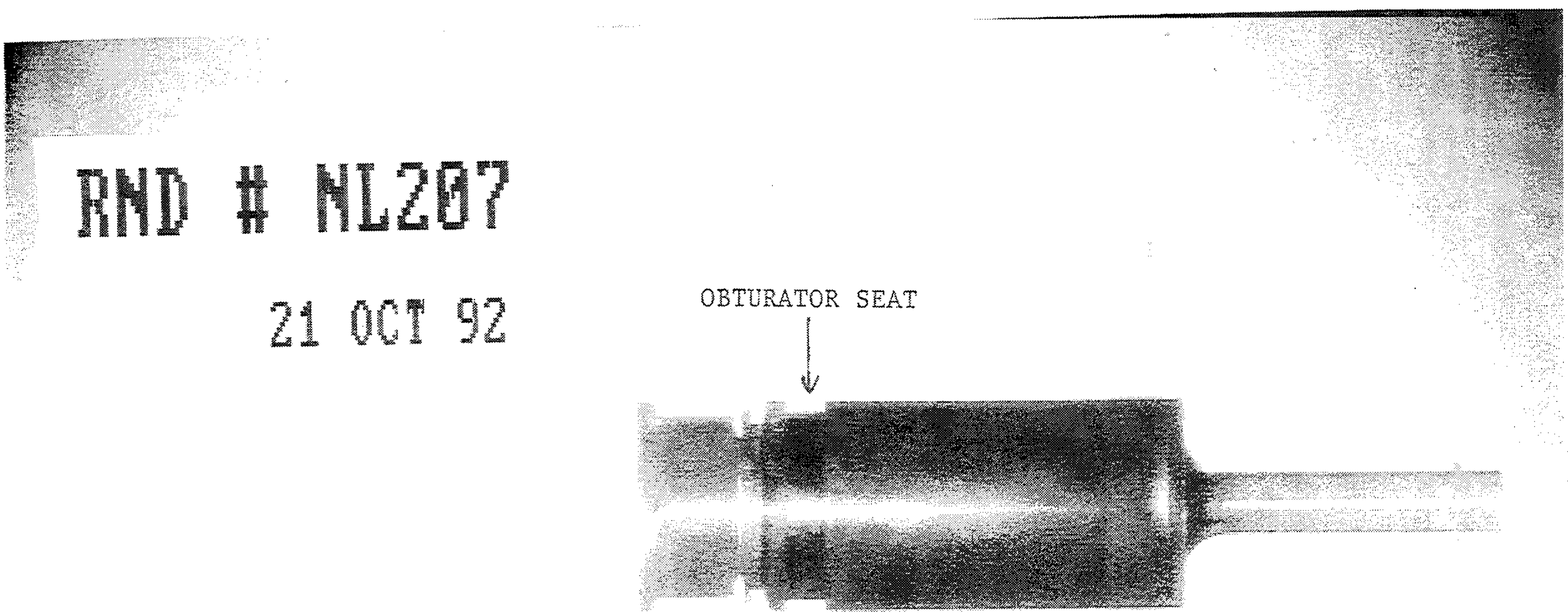


Cartridge, 120-mm, TP-T, M831

Figure 2
Cartridge, 120-mm HEAT-MP-T, M830 and cartridge, 120-mm, TP-T, M831



In-flight projectile with obturator



In-flight projectile with discarded obturator

Figure 3
M831A1 in-flight projectile

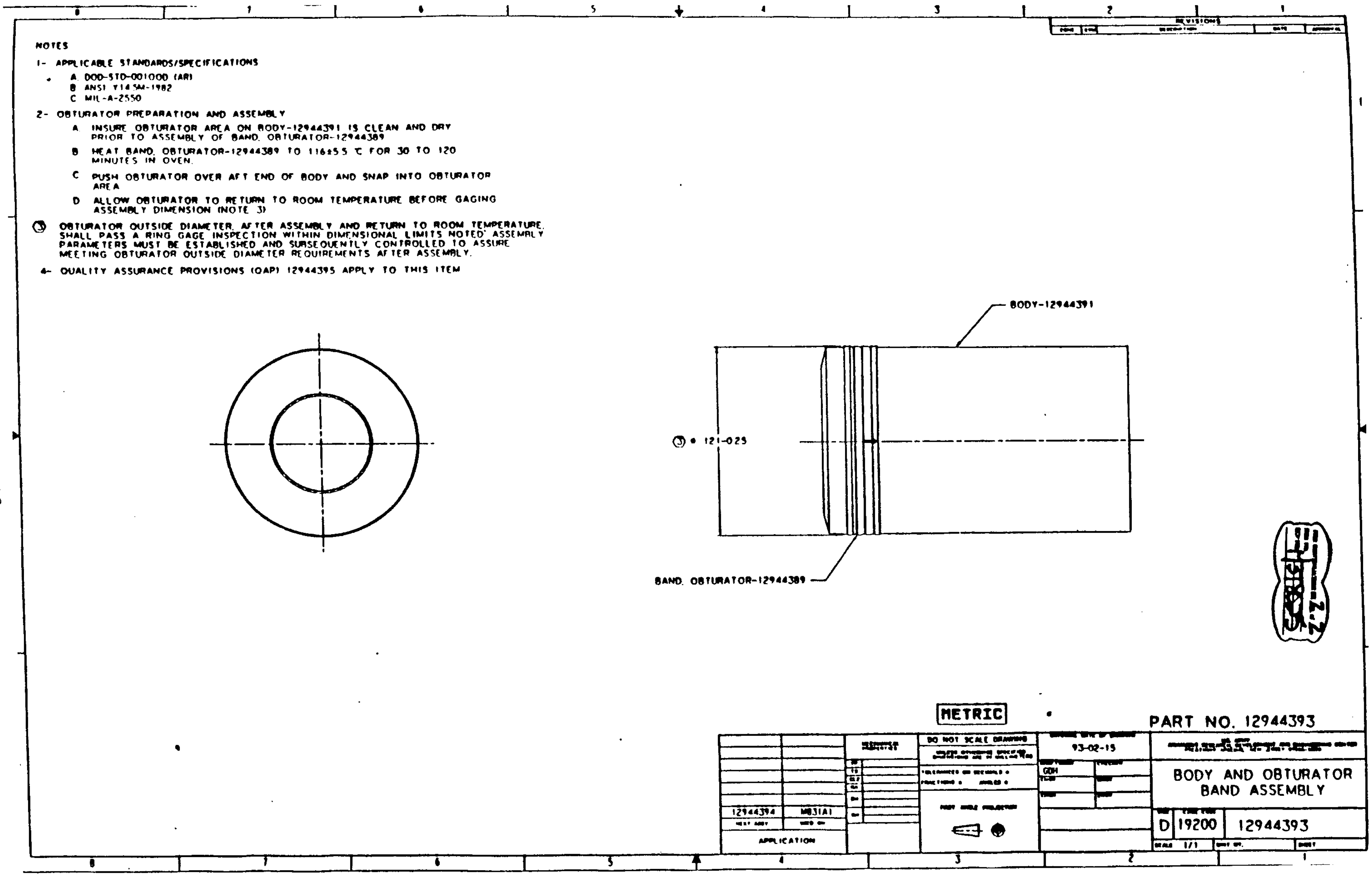


Figure 4
Obturator band assembly

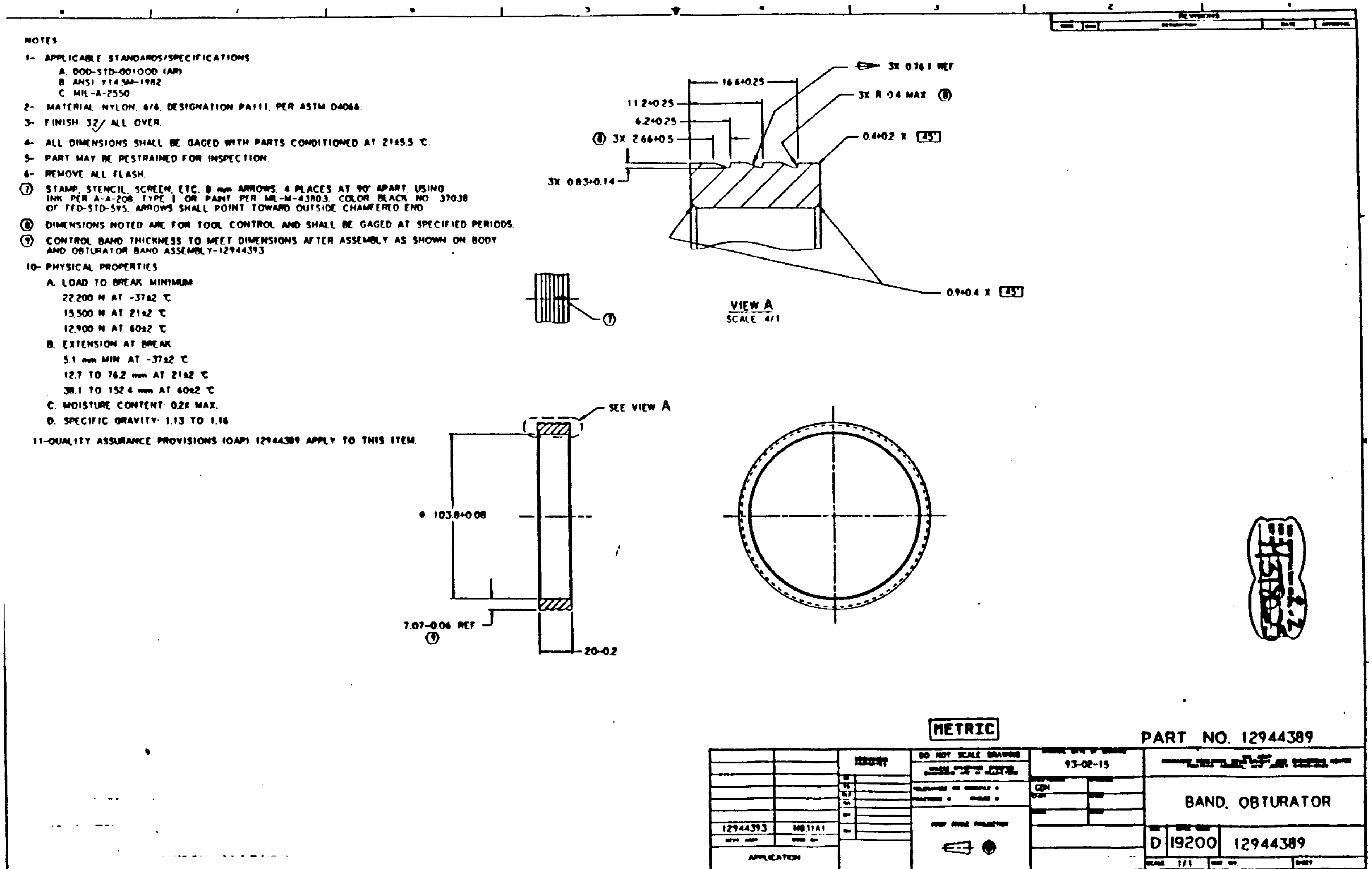


Figure 5
M831A1 obturator band physical requirements

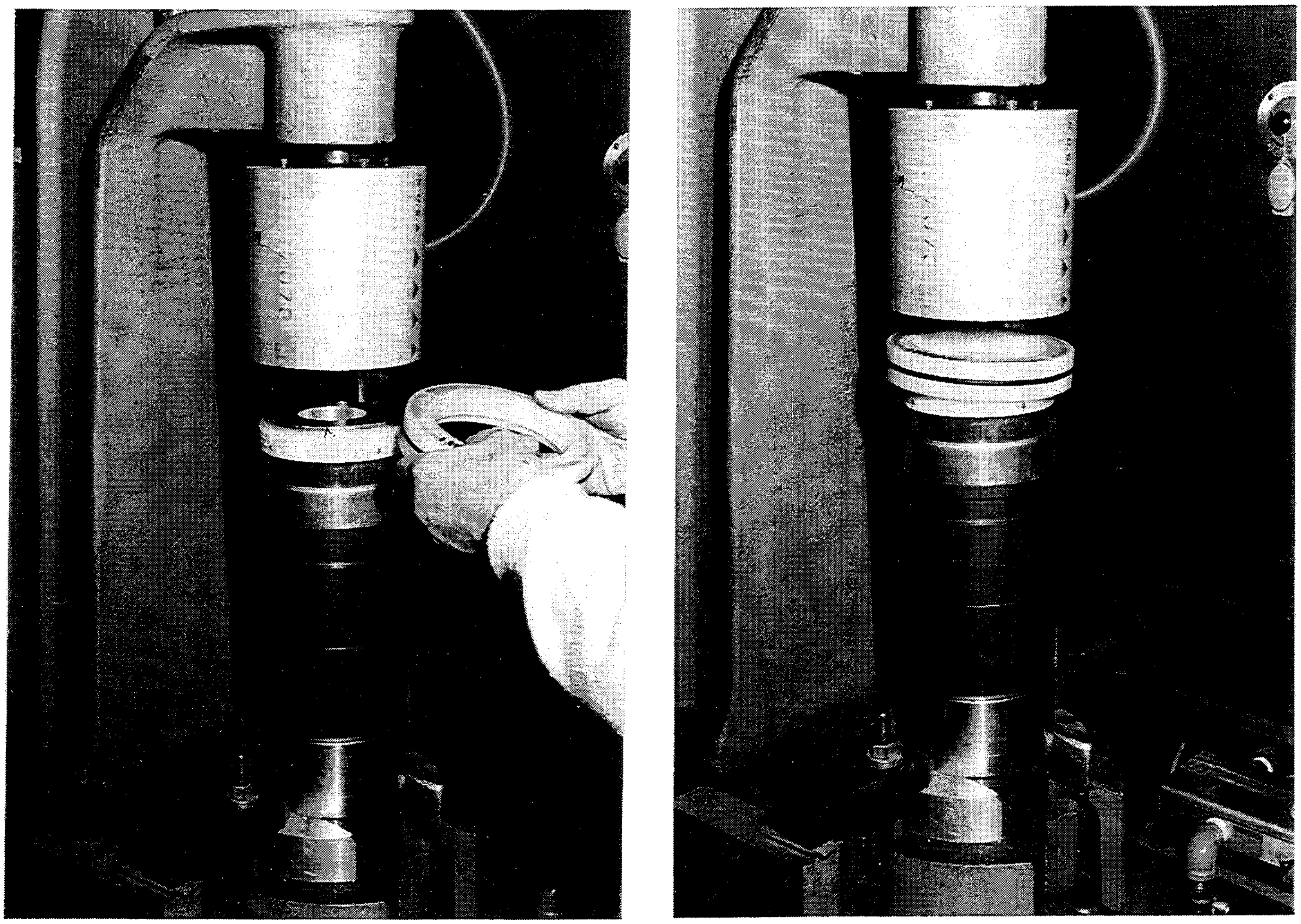


Figure 6
ARDEC setup for obturator installation

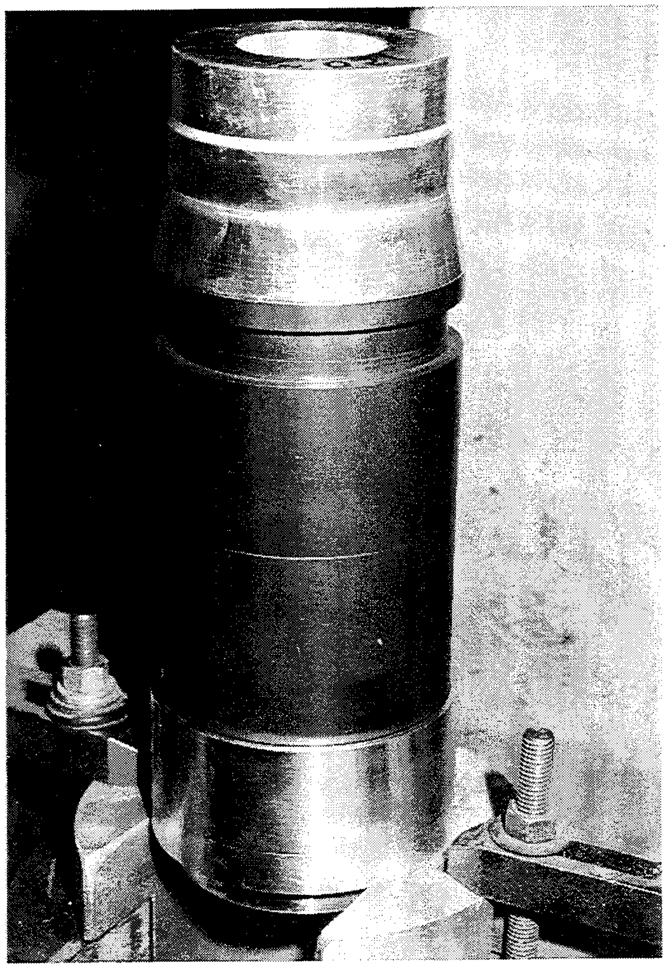


Figure 7
Aluminum ramp for obturator assembly

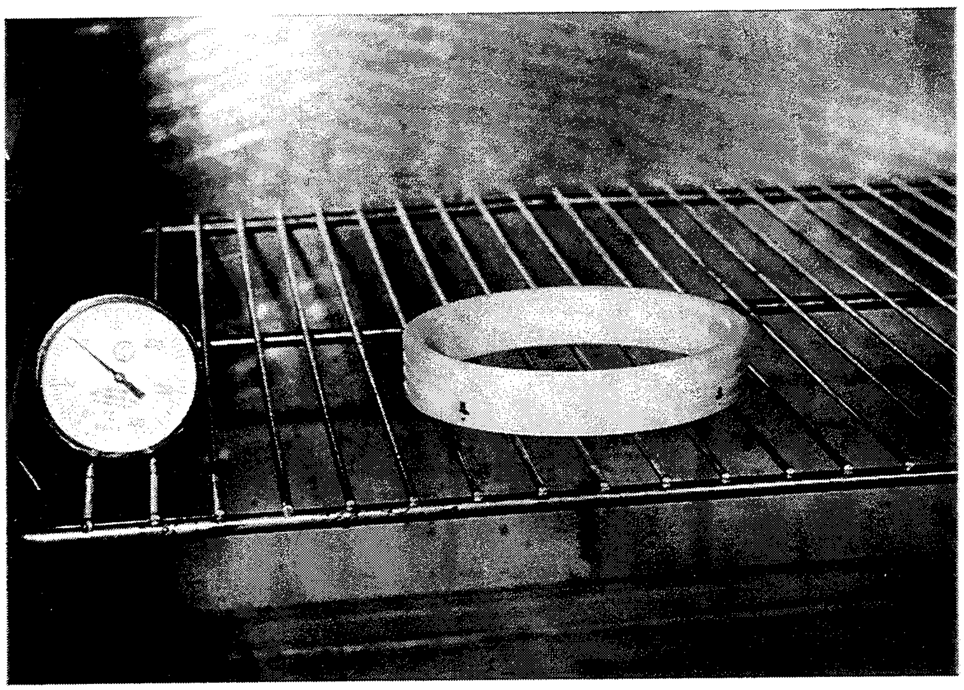
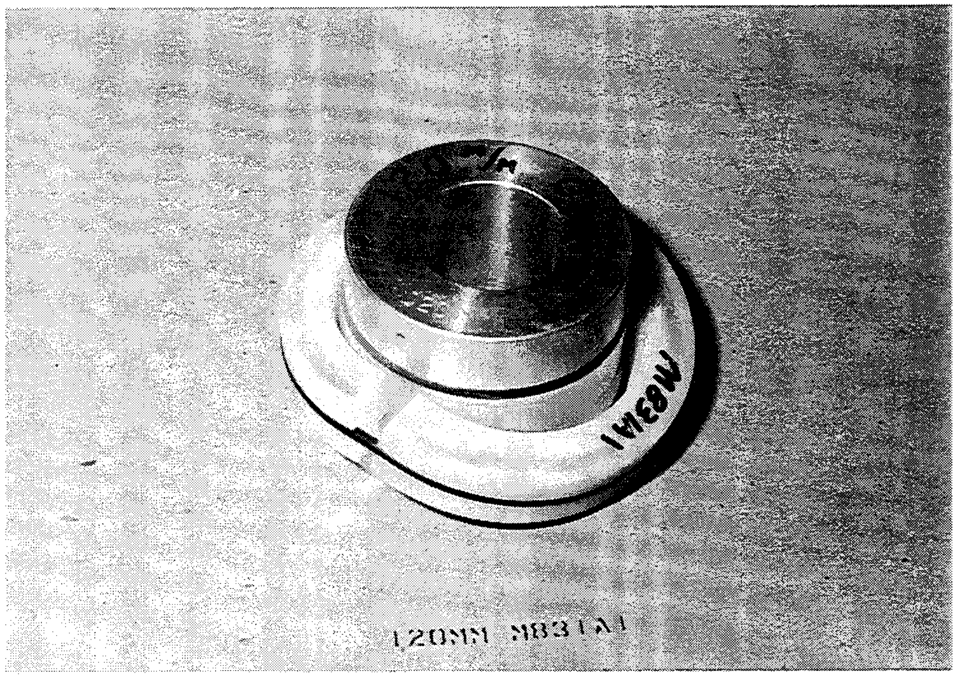


Figure 8
Obturator being temperature conditioned in oven



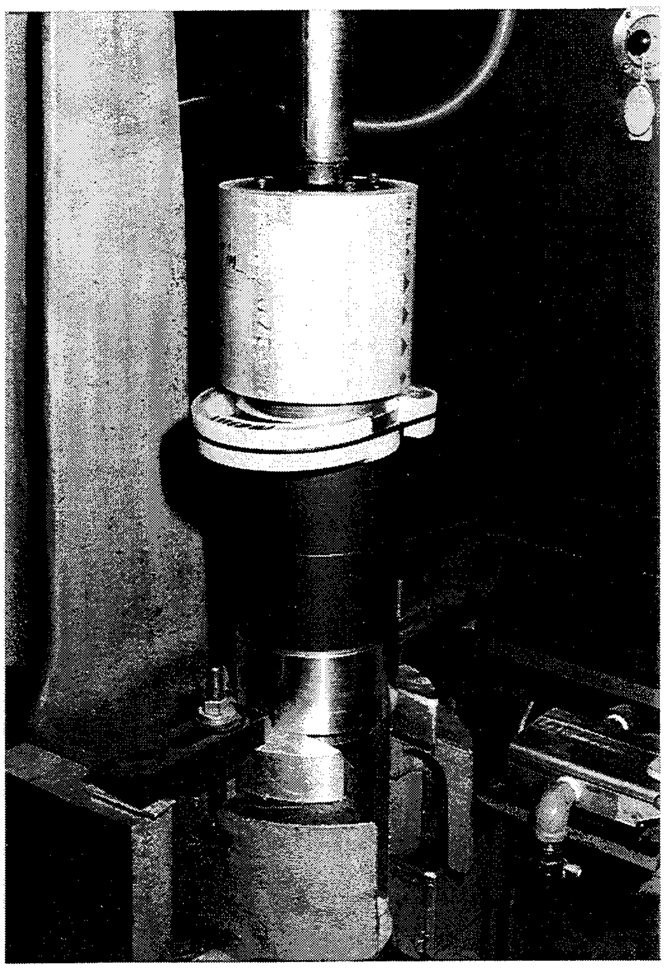
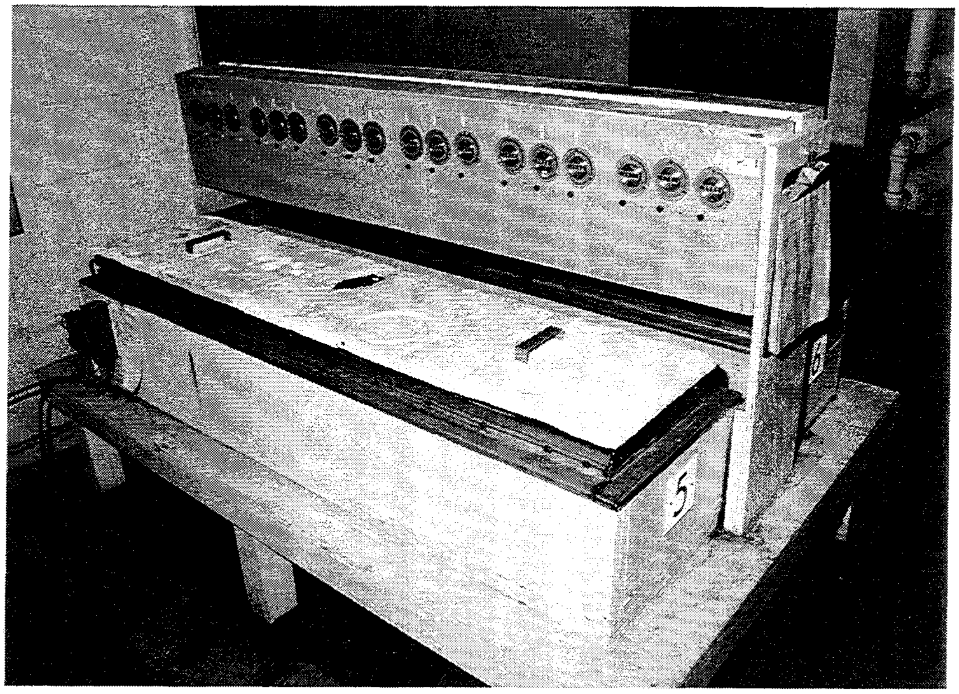


Figure 9
Nylon pusher for press



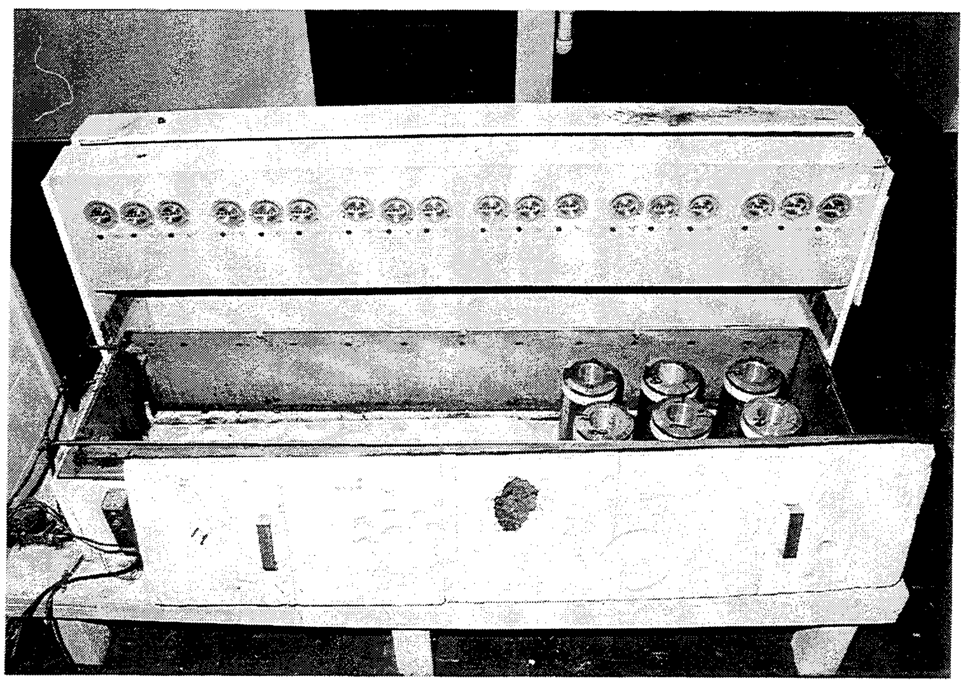


Figure 10
Temperature/humidity cabinet

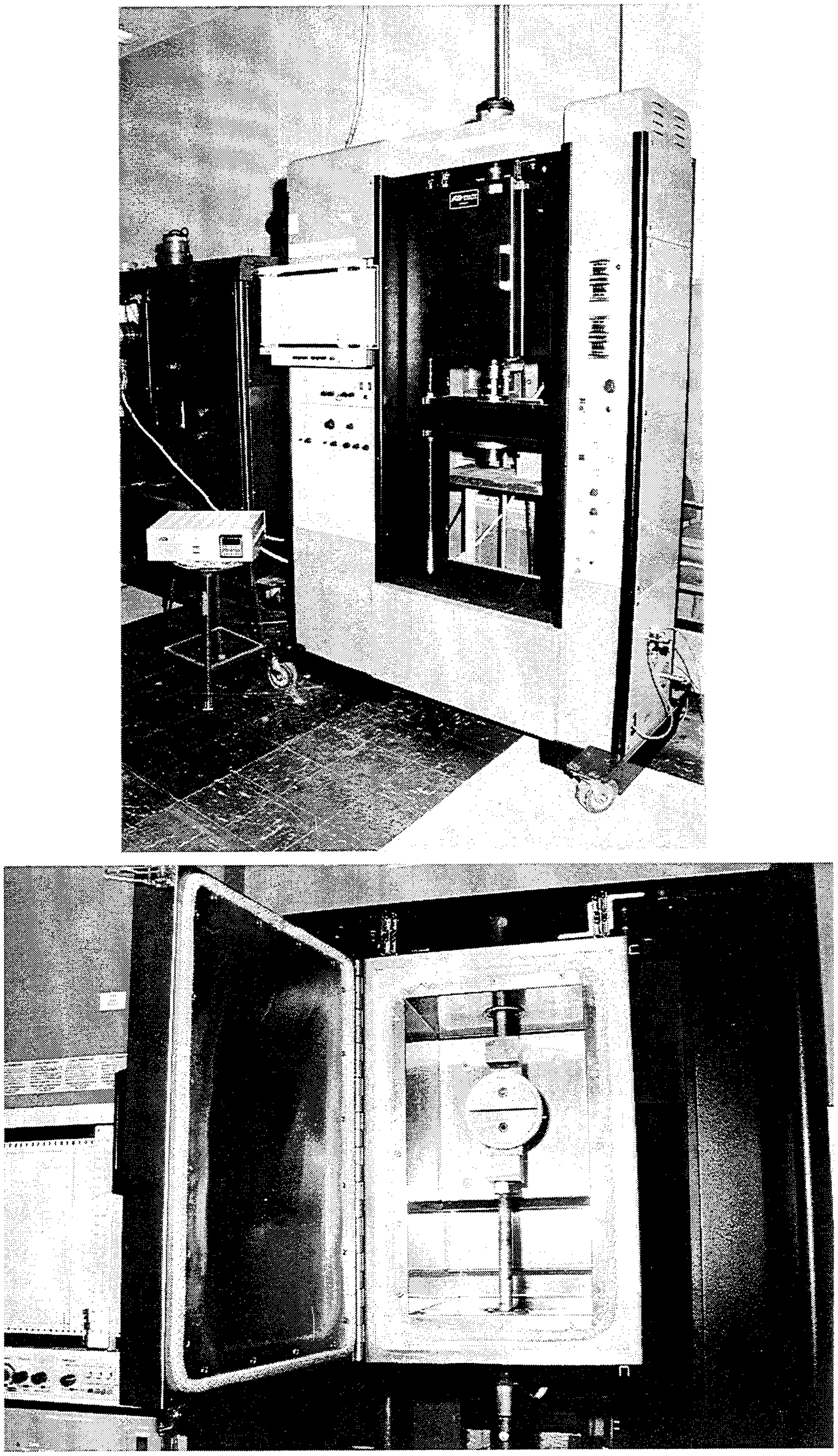


Figure 11
Instron tensile tester

Table 1
Results for temperature/humidity testing of M831A1, obturator/bodies for test 1

Test item (measurements in two locations)	Beginning measurements diameter (in.)	24 hrs 145°F/95% RH diameter (in.)	24 hrs 145°F/95% RH ring gage (Y/N)	Additional 5 days 145°F/95% RH diameter (in.)	Additional 5 days 145°F/95% RH ring gage (Y/N)
NC 1-1	4.762	4.758		4.772	
1-2	4.769	4.768	N	4.778	N
NC 2-1	4.764	4.763		4.788	
2-2	4.763	4.765	N	4.777	N
NC 3-1	4.758	4.763		4.764	
3-2	4.758	4.769	N	4.770	N
NC 4-1	4.760	4.762		4.775	
4-2	4.762	4.763	N	4.762	N
NC 5-1	4.761	4.764		4.779	
5-2	4.760	4.764	N	4.772	N
C 1-1	4.755	4.758		4.790	
1-2	4.754	4.757	Y	4.781	N
C 2-1	4.757	4.756		4.793	
2-2	4.756	4.756	Y	4.765	N
C 3-1	4.756	4.754		4.770	
3-2	4.754	4.753	Y	4.771	N
C 4-1	4.756	4.756		4.774	
4-2	4.754	4.756	Y(Tight)	4.771	N
C 5-1	4.754	4.752	Y	4.766	
5-2	4.755	4.758		4.764	N
C 6-1	4.755	4.755	Y	4.775	
6-2	4.758	4.757		4.773	N
C 7-1	4.756	4.763		4.780	
7-2	4.756	4.769	N	4.780	
C 8-1	4.755	4.757		4.781	
8-2	4.756	4.758	Y(Tight)	4.776	
C 9-1	4.757	4.758		4.773	N
9-2	4.754	4.754	Y(Tight)	4.777	N
C 10-1	4.757	4.752	Y	4.765	
10-2	4.756	4.756		4.787	N
W 1-1	4.755	4.756		4.764	
1-2	4.755	4.757	Y	4.765	N
W 2-1	4.757	4.754	Y	4.767	N
2-2	4.756	4.757		4.766	
W 3-1	4.756	4.756	Y	4.768	
3-2	4.758	4.754		4.765	N
W 4-1	4.757	4.758	Y	4.778	N
4-2	4.758	4.758		4.774	
W 5-1	4.755	4.758	Y	4.767	
5-2	4.757	4.757		4.765	N

Table 2
Results for temperature/humidity testing of M831A1, obturator/bodies for test 2

Test item (measurements in two locations)	Beginning measurements diameter (in.)	3 days 70°F/RH unknown diameter (in.)	3 days 70°F/RH unknown ring gage (Y/N)	Additional 12 days 95°F/95% RH diameter (in.)	Additional 12 days 95°F/95% RH ring gage (Y/N)	Obturator loose tight (L/T)
NC 1-1	4.755	4.754		4.763	N	L
1-2	4.757	4.753	Y	4.771		
NC 2-1	4.759	4.752		4.770	N	L
2-2	4.759	4.755	Y	4.768		
NC 3-1	4.764	4.762		4.772	N	L
3-2	4.763	4.756	Y	4.770		
NC 4-1	4.754	4.755		4.767	N	T
4-2	4.763	4.757	Y	4.768		
NC 5-1	4.762	4.753		4.763	N	T
5-2	4.761	4.754	Y	4.768		
NC 6-1	4.761	4.755		4.767	N	L
6-2	4.760	4.756	Y	4.765		
NC 7-1	4.761	4.747	Y	4.766	N	L
7-2	4.761	4.750		4.767		
C 1-1	4.753	4.757		4.769	Y	T
1-2	4.753	4.759	Y	4.769		
C 2-1	4.756	4.759		4.772	N	T
2-2	4.756	4.761	Y	4.771		
C 3-1	4.752	4.758		4.780	N	L
3-2	4.753	4.761	Y	4.778		
C 4-1	4.753	4.757		4.774	N	L
4-2	4.752	4.760	Y	4.774		
C 5-1	4.753	4.761		4.773	N	T
5-2	4.750	4.759	Y	4.774		
C 6-1	4.754	4.760		4.772	N	T
6-2	4.752	4.761	Y	4.771		
C 7-1	4.751	4.756		4.778	N	T
7-2	4.752	4.758	Y	4.773		
W 1-1	4.754	4.754		4.763	N	L
1-2	4.756	4.756	Y	4.762		
W 2-1	4.754	4.755	Y	4.760	N	L
2-2	4.762	4.765		4.768		
W 3-1	4.753	4.754	Y	4.762	N	T
3-2	4.755	4.753		4.761		
W 4-1	4.754	4.753		4.755	Y	T
4-2	4.754	4.755	Y	4.757		
W 5-1	4.754	4.753		4.757	Y	T
5-2	4.754	4.754	Y	4.758		
W 6-1	4.752	4.752		4.758	Y	T
6-2	4.753	4.753	Y	4.758		
W 7-1	4.753	4.753		4.758	Y	T
7-2	4.753	4.754	Y	4.758		

Table 3
Results for oven (low humidity) testing of M831A1, obturator/bodies for test 3

Test item (measurements in two locations)	Beginning measurements diameter (in.)	3 days 95°F diameter (in.)	3 days 95°F ring gage (Y/N)	Additional 7 days diameter (in.)	Additional 7 days ring gage (Y/N)	Obturator loose (L/T)
NC 1-1	4.761	4.756		4.753		
1-2	4.758	4.753	Y	4.754	Y	T
NC 2-1	4.757	4.757		4.752		
2-2	4.757	4.757	Y	4.754	Y	T
NC 3-1	4.760	4.757		4.754		
3-2	4.760	4.757	Y	4.753	Y	T
C 1-1	4.754	4.750		4.751		
1-2	4.752	4.751	Y	4.756	Y	T
C 2-1	4.752	4.751		4.753		
2-2	4.756	4.758	Y	4.757	Y	T
C 3-1	4.752	4.752		4.752		
3-2	4.750	4.753	Y	4.752	Y	T
W 1-1	4.755	4.752		4.753		
1-2	4.754	4.754	Y	4.752	Y	T
W 2-1	4.754	4.755		4.757		
2-2	4.754	4.753	Y	4.757	Y	T
W 3-1	4.747	4.750		4.751		
3-2	4.747	4.753	Y	4.752	Y	T

Table 4
Results for temperature/humidity testing of M831A1,
obturator/bodies for test 4

Test item (measurements in in two locations)	Beginning measurements diameter (in.)	7 days 95°F/95% RH diameter (in.)	7 days 95°F/95% RH ring gage (Y/N)	7 days 145°F/95% RH diameter (in.)	7 days 145°F/95% RH ring gage (Y/N)
*NEW PROCEDURE (NP)					
NP 2-1	4.757	4.754	Y	4.767	N
2-2	4.759	4.752		4.766	
NP 3-1	4.756	4.754	Y	4.762	N
3-2	4.763	4.754		4.785	
NP 4-1	4.753	4.754	Y	4.766	N
4-2	4.758	4.762		4.766	
NP 5-1	4.752	4.753	Y	4.773	N
5-2	4.753	4.754		4.765	
NP 6-1	4.761	4.757	Y	4.773	N
6-2	4.757	4.752		4.762	
NP 7-1	4.756	4.755	Y	4.768	N
7-2	4.755	4.757		4.769	
NP 1-1	4.757	4.753	Y	4.760	Y
1-2	4.755	4.754		4.759	
NP 5-1	4.755	4.755	Y	4.773	N
5-2	4.755	4.754		4.759	
NP 6-1	4.752	4.754	Y	4.750	Y
6-2	4.755	4.754		4.761	

Table 5
Physical property test results on M831A1 obturators

Specimen number	Outer diameter	Inner diameter	Thickness	Height	Weight	Pounds load	Elongation
ROOM TEMPERATURE							
1	4.640	4.091	0.278	0.783	53.7234	5,250	1.40
2	4.643	4.095	0.278	0.782	53.7098	5,650	1.17
3	4.642	4.093	0.278	0.782	53.7042	4,900	1.60
4	4.639	4.092	0.278	0.782	53.6807	500	1.31
5	4.640	4.093	0.278	0.783	53.7128	4,900	1.25
AVG						4,240	1.35
S.D.						2,114	0.17
+140 DEGREES F							
6	4.641	4.091	0.278	0.782	53.6895	420	3.22
7	4.643	4.089	0.278	0.782	53.6855	3,700	6.00+
8	4.642	4.089	0.278	0.783	53.7278	3,660	5.70
9	4.639	4.090	0.278	0.783	53.7492	3,650	6.00+
10	4.639	4.091	0.278	0.783	53.7346	3,650	3.25
AVG						3,016	4.06
S.D.						1,451	1.42
-35 DEGREES F							
11	4.640	4.092	0.278	0.782	53.7265	6,550	1.00
12	4.640	4.092	0.278	0.782	53.6927	200	0.90
13	4.640	4.095	0.278	0.781	53.6927	700	0.88
14	4.639	4.091	0.278	0.782	53.6915	6,550	0.90
15	4.639	4.092	0.278	0.782	53.6884	690	0.86
AVG						2,938	0.91
S.D.						3,304	0.05
TEMPERATURE HUMIDITY 1 WEEK							
16	4.460	4.090	0.279	0.783	53.7588	3,800	2.75
17	4.640	4.091	0.280	0.783	53.7561	200	2.05

APPENDIX

TEMPERATURE/HUMIDITY TEST PLANS

Test Plan 1

Determination of Effect on M831A1 Obturator Bands Which Have Been Subject to High Temperature Conditions

Materials Supplied

10 M831A1 bodies with obturator bands (clamp procedure was used)

10 M831A1 bodies with obturator bands (clamp procedure was not used)

5 M831A1 bodies with boiled obturator bands (clamp not used)

20 M831A1 obturator bands

1 Ring gage (may or may not be supplied)

1 Drawing 12944389, band obturator

2 Split M831A1 obturators wich were assembled on a M831A1 body and were found to be out of round and removed

Test

Measure the obturator bands on the 25 M831A1 bodies in two locations which were premarked. Two different color magic marker marks are on the band and body. They are approximately 90 deg apart.

Place the 25 bodies in an oven for 1 day at 145°F and a relative humidity (RH) of approximately 95%.

Remove from the oven and let cool for 24 hrs at room temperature. Record room temperature and remeasure the 256 obturator bands in the same location as before. Do not measure or touch the obturator bands when first removed from the oven. This may artifically create an out of round condition for the hot bands. This precaution is to be adhered to through out this test plan.

Place the 25 bodies back into the oven for 14 days at 145°F.95% RH. Remove the 25 bodies, allow to cool at room temperature for 24 hrs and remeasure as before.

Place the 25 bodies back into the oven for 15 days at 145°F/95% RH. Remove the 25 bodies, allow to cool at room temperature for 24 hrs, and remeasure as before. If Close Combat Armaments Center (CCAC) supplies ring gage, record if bodies are go/no go.

Measure the 20 obturator bands that were supplied separately and were not attached to bodies. Measurements should include the I.D., O.D., and thickness of the bands. Check for roundness of the I.D. and O.D. of the bands.

Perform the testing found on drawing 12944389, physical properties: Load to break, extension at break, moisture content, and specify gravity. Load to break and extension to break shall have five each tested at -37° ± 2°C, 21° ± 2°C, and 60° ± 2°C. The moisture content and specific gravity shall have two each tested.

Examine the split obturators supplied by microscope or other means to determine if the nylon structure in the out of round location is different from the structure of the in round location. Locations will be already marked.

Extra obturator bands may be supplied for test purposes. AED may use their judgement as to further tests to do with these bands, such as placing them in the oven to study effects without the body.

Time Schedule

Material shall be supplied by 1 September 1995.

Temperature/humidity testing shall be completed by AED within 40 days of receipt of material from CCAC.

All test results shall be informally supplied from AED to CCAC within 2 days of completion of testing. A formal report shall be supplied within 1 mo of completion of testing.

Test Plan 2

Determination of Effect on M831A1 Obturator bands Which Have Been Subject to High Temperature/Humidity Conditions

Materials Supplied

10 M831A1 bodies with obturator bands (clamp procedure was used)

10 M831A1 bodies with obturator bands (clamp procedure was not used)

10 M831A1 bodies with boiled obturator bands (clamp not used)

Test

Measure the obturator bands on the M831A1 bodies in two locations which were premarked. Two different color magic marker marks are on the band and body. They are approximately 90 deg apart.

Ring gage the bodies and record go or no go.

Place the bodies in anoven for 3 days at 70°F and a relative humidity (RH) of approximately 95%.

Remove from the oven and let cool for 24 hrs at room temperature. Record room temperature and remeasure the obturator bands in the same location as before. Do not measure or touch the obturator bands when first removed from the oven. This may artifically create an out of round condition for the hot bands. This precaution is to be ashered to through out this test plan.

Ring gage the bodies and record go or no go.

Place the bodies back into the oven for 7 days at 95°F/95% RH. Remove the bodies, allow to cool at room temperature for 24 hrs and remeasure as before.

This concludes the obturator test. Please prepare final report due within 1 mo from completion of test. An informal report with the data should be submitted as soon as possible.

Time Schedule

Material shall be supplied by 2 October 1995.

Temperature/humidity testing shall be completed by AED within 2 wks of receipt of material from CCAC.

All tests results shall be informally supplied from AED to CCAC within 2 days of completion of testing. A formal report shall be supplied within 1 mo of completion of testing.

M831A1 OBTURATOR TEST RESULTS

1 WEEK TEMPERATURE/HUMIDITY SAMPLES

WEIGHT DETERMINATION

SPECIMEN NUMBER	INITIAL WEIGHT	CONDITIONED WEIGHT	DRIED WEIGHT
16	53.7588	54.7716	53.7605
17	53.7561	54.7931	53.7339
18	53.7146	54.4260	53.7586
19	53.7557	54.8788	53.7803
20	53.3028	54.8087	53.7278

2 WEEK TEMPERATURE/HUMIDITY SAMPLES

WEIGHT DETERMINATION

SPECIMEN NUMBER	INITIAL WEIGHT	CONDITIONED WEIGHT	DRIED WEIGHT
21	53.7605	55.4145	55.4210
22	53.7339	55.5480	55.5488
23	53.7586	55.4047	55.4148
24	53.7803	55.1379	55.1501
25	53.7278	55.2540	55.2609

SPECIFIC GRAVITY (1.13 TO 1.16)

SPECIMEN	SP G
A	1.15
B	1.15

MOISTURE CONTENT (.2 MAX)

SPECIMEN	INITIAL	24 HOURS	48 HOURS	72 HOURS	144 HOURS
C	53.7505	53.6609	53.6336	53.6260	53.6096
D	53.8943	53.7888	53.7682	53.7583	53.7373

	168 HOURS	192 HOURS	%MOISTURE
C	53.6099	53.6093	0.26
D	53.7371	53.7373	0.29

18	4.639	4.092	0.278	0.782	53.7146	225	1.50
19	4.641	4.092	0.278	0.783	53.7557	270	1.70
20	4.640	4.091	0.278	0.782	53.7302	90	1.60
AVG						917	1.92
S.D.						1,613	0.51
21	4.638	4.092	0.278	0.783	53.7605	2,050	0.66
22	4.638	4.091	0.278	0.782	53.7339	100	0.55
23	4.639	4.091	0.278	0.783	53.7586	1,700	0.64
24	4.639	4.090	0.278	0.783	53.7804	175	2.17
25	4.639	4.091	0.278	0.783	53.7278	2,900	1.16
AVG						1,385	1.04
S.D.						1,220	0.69

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